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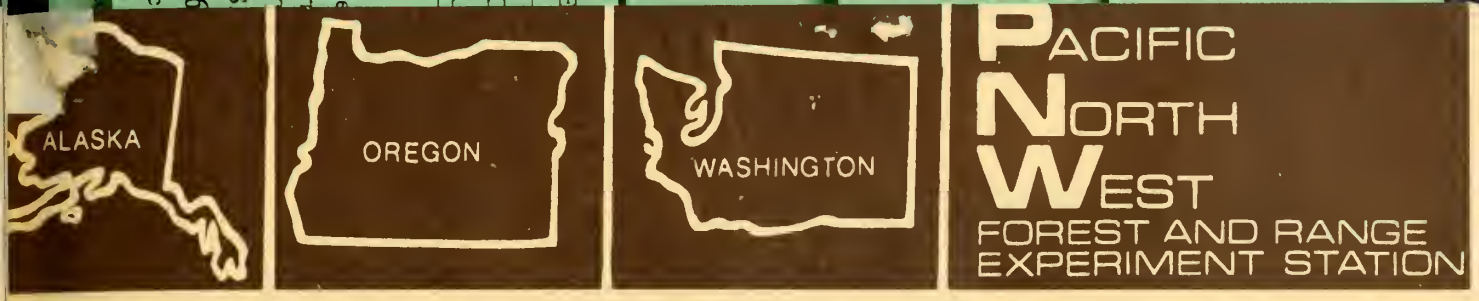

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RUNNING SKYLINE DESIGN WITH A DESK-TOP COMPUTER/PLOTTER

by

Ward W. Carson, *Mechanical Engineer*
Pacific Northwest Forest & Range Experiment Station
Seattle, Washington

Donald Studier, *Civil Engineer*
Gifford Pinchot National Forest
Vancouver, Washington

Hilton H. Lysons, *Industrial Engineer*
Pacific Northwest Forest & Range Experiment Station
Seattle, Washington

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ABSTRACT

The procedure for determination of running skyline load-carrying capability is discussed. A desk-top computer/plotter is employed to plot terrain profiles and determine and plot the path of a loaded running skyline carriage. The computer programs implementing the procedure are included. The paper is intended for the designer who is investigating the use of running skylines in harvesting plans.

Keywords: Skyline logging, logging operations, computer programs, logging.

1.0 INTRODUCTION

The running skyline system is being used by an increasing number of timber operators for thinning and clearcutting. It is a system of two or more suspended moving lines, generally referred to as main and haulback, that when properly tensioned will provide lift and travel to the suspended load.[1/] A grapple-rigged system is illustrated in figure 1.

The logging system designer who is considering the application of a running skyline system must determine its load-carrying capability over a given ground profile. There are basically three means for assessing this capability: a graphical-tabular handbook approach as presented by Lysons and Mann,[2/ 3/] a mathematical solution utilizing the large digital computing facilities,[4/] or a mathematical solution utilizing small desk-top computers. All these methods are directed to the problem of determining the load-carrying capability of running skylines; however, there is a difference in approach. The procedures presented in references 2, 3, and 4 determine the load that can be carried under given conditions of deflection, whereas the desk-top computer approach presented here determines deflection, and ultimately a load path, for a specified load. This note discusses the approach and the implementation of solution on the desk-top computer. The mathematical features of the problem are discussed in a paper by Carson and Mann.[5/]

[1/] Anonymous. Glossary of cable logging terms. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv., 7 p., 1969.

[2/] Hilton H. Lysons and Charles N. Mann. Skyline tension and deflection handbook. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-39, 41 p., illus., 1967.

[3/] Charles N. Mann. Mechanics of running skylines. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-75, 11 p., illus., 1969.

[4/] Stanley K. Suddarth. Analysis of cable systems--the grapple-rigged running skyline. Skyline Logging Symp. Proc., Oreg. State Univ., 1970.

[5/] Ward W. Carson and Charles N. Mann. Analysis of running skyline load path. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. In preparation.

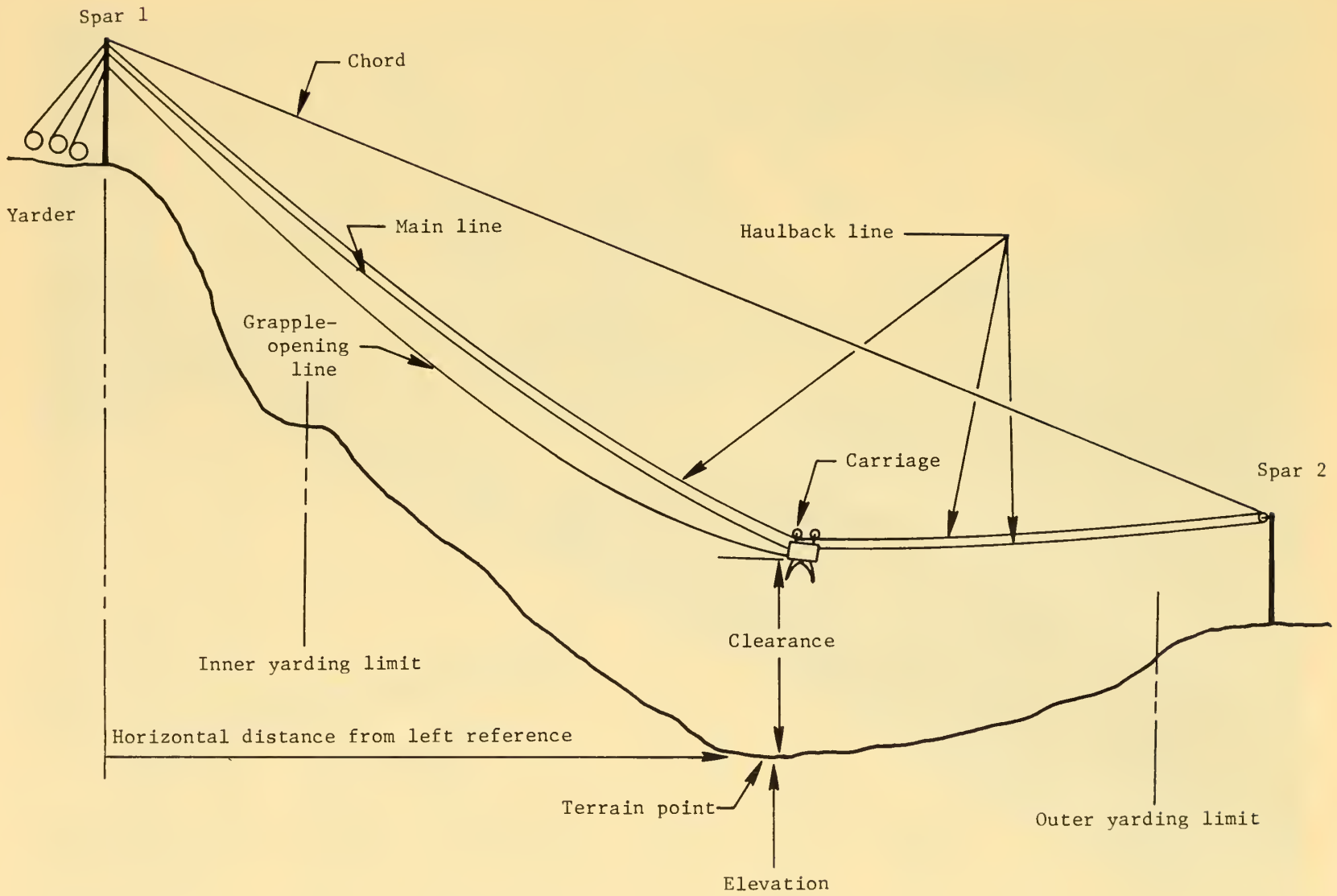

Figure 1.—Running skyline nomenclature.

2.0 DESK-TOP COMPUTER SYSTEM

The recent development of desk-top computers and plotters now makes it possible to obtain on-the-job solutions of many problems that previously were referred to large central computing facilities. These desk-size machines have memories that enable them to store instructions and constants for repetitive or iterative solutions. The programs for these computers are written in keyboard language and can be stored magnetically when desired. The capability of the computer is determined by the number of storage registers that it provides.

A plotter and a printer may be used in conjunction with the computer. The plotter provides a graphic display of the solutions to the problems solved. It plots the points specified by the calculator when instructed to do so.

The printer will print the contents of the calculator's display registers upon manual or programed command. It can also list the contents of the calculator's program memory.

A typical desk-top computer system is shown in figures 2, 3, and 4.

3.0 PHYSICAL PROBLEM

To determine the feasibility of individual skyline roads in a logging plan, the designer must compute the capability of the running skyline system. Capability is a function of both allowable line tension and deflection which is limited by terrain. Line tensions are controlled by the yarder, and the deflection of the system results from the load which is being supported. The profile of the skyline road is established by the designer from ground profile data, obtained from contour maps, stereophotograph models, or from ground measurements. The designer specifies the cable sizes and an operating tension in the haulback line. The question at this point of design is "Will the anticipated load clear the ground profile?" The answer can be provided by a desk-top computer.

The anticipated load on a running skyline varies with the conditions of the operation. If there is a requirement to "fly" logs clear of the ground, the total weight must be supported by the lines, and clearance must be provided above the ground. If the logs can be yarded with one end resting on the ground, which is generally the case when logging uphill or on level ground, the lines support only the weight of the carriage and a fraction of the weight of the logs. Allowing some ground support of the logs also reduces clearance requirements which, in turn, increases capability.

Figure 2.—Calculator, printer, and plotter combination.

Figure 3.—Calculator keyboard.

Figure 4.—Calculator plotter with sample output.

In general, the designer must establish his requirements for payload capability and ground clearance and determine whether the proposed equipment and ground profile will allow the path of the specified load to maintain the necessary clearance. An optimum design resulting from a first trial is highly improbable, but the designer's direct access to a desk-top computer makes it possible to quickly optimize by modifying the design.

An example will illustrate the problem. Consider a running skyline with 7/8-inch haulback, main, and grapple-opening lines. The span length is 800 feet, with a profile as indicated on the plot. The headspar is 50 feet tall, and the tailspar is 20 feet tall. Since in this example the logs are allowed to be yarded with one end on the ground, a minimum clearance of 10 feet is required below the load path. A payload of 10,000 pounds, to be supported by the skyline, is judged to be adequate considering that, in this example, one end of the load is supported by the ground. The carriage is assumed to weigh 1,000 pounds, which results in a gross payload requirement of 11,000 pounds.

4.0 PROBLEM SOLUTION

To solve the problem with a desk-top computer, the designer enters the station and elevation coordinates of terrain profile points and spar heights while the plotter, driven by the computer, plots the profile and the spars. Next, the designer enters the line weight, allowable tension, and a trial payload. The plotter traces the path of this load between the spar anchor points. At the same time, the computer shows the station and elevation coordinates of the load path. If the load path intersects the ground or fails to allow sufficient clearance, the designer can immediately test another load path with a lesser payload. The results may also indicate enough clearance to allow an increase in payload or the need to alter span length or location.

Figure 5 shows the solution of the hypothetical problem described earlier. A trial with an 11,000-pound gross payload provides a load path which clears all of the terrain points, with room to spare. A gross payload (log weight plus 1,000-pound carriage weight) of 25,000 pounds results in a carriage load path which comes within 10 feet of a terrain point. Therefore, this skyline road will allow a net payload of 24,000 pounds to be supported by the skyline. If the designer assumes that 40 percent of the log load is supported by the ground, the total log weight can be

$$W = \frac{24,000}{0.6} = 40,000 \text{ pounds.}$$

The load paths for the 11,000-pound and the 25,000-pound gross payloads are shown in figure 5.

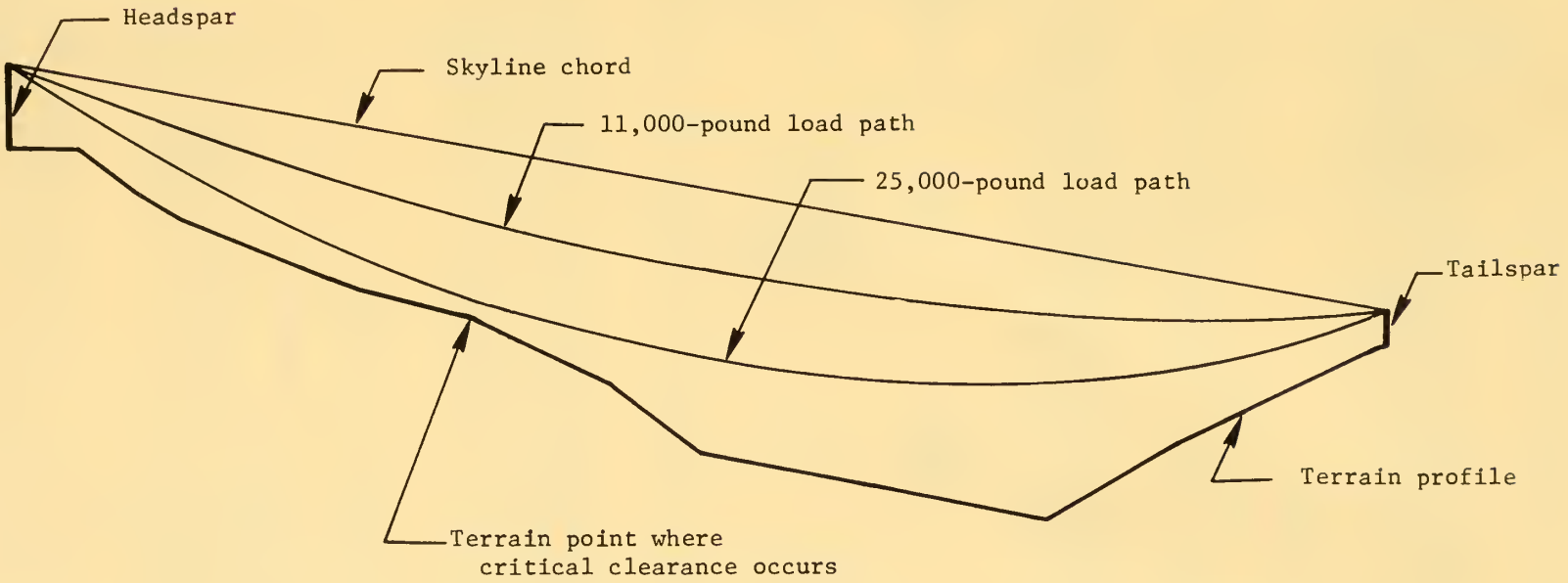

Figure 5.—Example of desk-top computer solution.

5.0 PROGRAMS FOR PROBLEM SOLUTION

A program for plotting the load path of the running skyline has been written for the Hewlett-Packard systems [6] from the force balance formulation discussed by Carson and Mann. [5] This program is used in conjunction with a profile plot program that was also written for the Hewlett-Packard system.

5.1 Profile Plot Program

This program will determine the scale of the plot, plot the ground profile, and plot the headspar, tailspar, and chord of the skyline.

The scale of the plot is determined by the computer from the span length and maximum ground elevation difference. It will choose the largest scale that will fit the 10-inch by 15-inch paper from the following:

Scale	Scale factor	x_{max}	Maximum ground elevation difference
1 inch = 50 feet	10	750 feet	450 feet
1 inch = 100 feet	5	1,500 feet	900 feet
1 inch = 200 feet	2.5	3,000 feet	1,800 feet
1 inch = 500 feet	1	7,500 feet	4,500 feet

The scale factors were computed from the plotter's scale factor of 500 counts per inch.

The operator can override the machine-selected scale factor by entering the program in the machine, entering the minimum elevation of the ground profile in the f register, entering the desired scale factor in the c register, and pressing Go To (3) (a). The program is then ready to accept x, y, and $HS1$ (see fig. 6).

Data needed to plot the profile are:

1. Maximum y_{max} and minimum y_{min} ground elevations.
2. Length of span (L).
3. Height of left, $HS1$, and right, $HS2$, spars.
4. Coordinates of terrain points in elevations and distance from the left spar tree (x, y).

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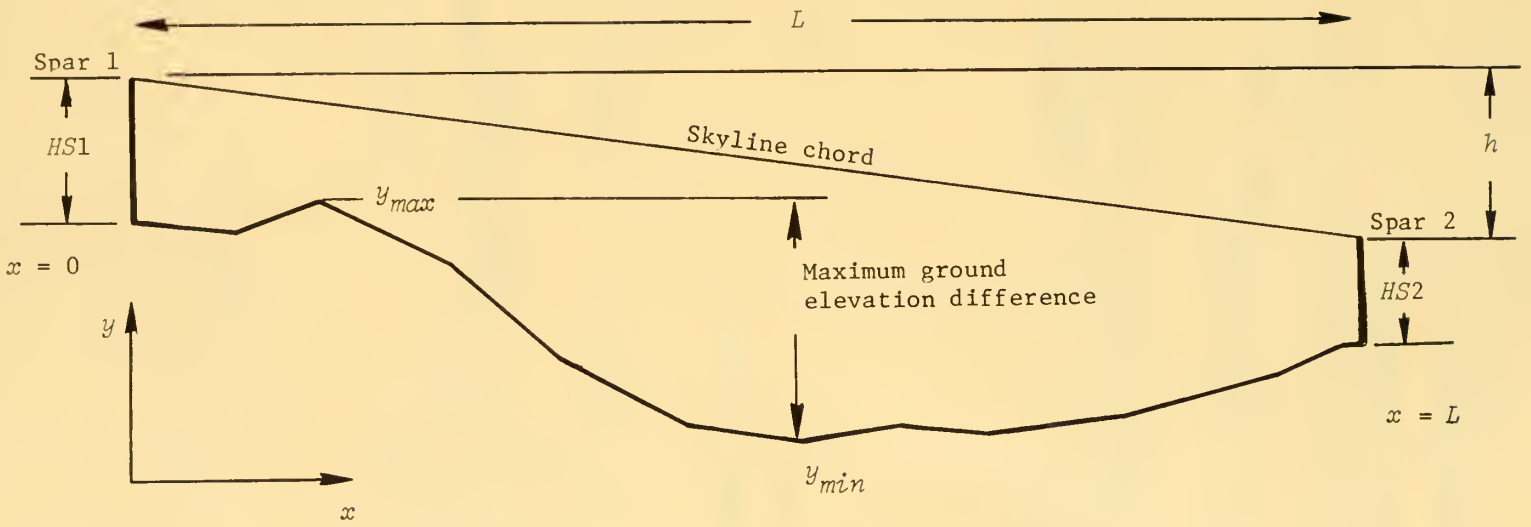
[6] The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U. S. Department of Agriculture of any product to the exclusion of others which may be suitable.



$HS1$ = height of spar 1
$HS2$ = height of spar 2
L = length of span (feet)
y_{max} = highest ground elevation (feet)
y_{min} = lowest ground elevation (feet)
x = distance measured from spar 1 (or from first terrain point)
s = percent slope of chord
y = elevation of terrain point (feet)
h = anchor elevation difference (feet)

Figure 6.—Nomenclature of the profile plot program.

The output includes:

1. Scale factor (for use by the load path program).
2. Ground profile plot.
3. Headspar, tailspar, and chord of the skyline.
4. Percent slope of chord (up and to the right is positive slope).

If a ground profile plot is desired without the headspar, tailspar, and skyline chord, the program should be modified as follows:

1. Enter zero for height of left spar ($HS1$).
2. After last terrain point instead of pressing Go To (6) (0), press STOP. The span length (L) will now be the length of the profile, and the horizontal distance (x) will be measured from the first terrain point.

5.1.1 Profile Plot Program Flow

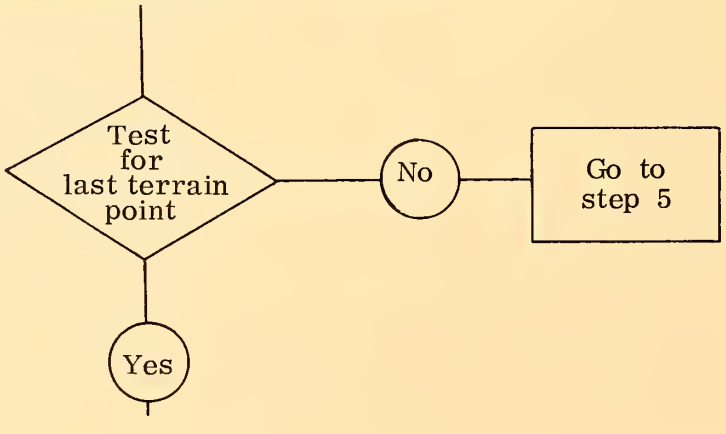
1. Input general dimensions:

L = skyline span,

y_{max} = highest ground elevation,

and

y_{min} = lowest ground elevation.

2. Determine and print scale factor.
3. Enter coordinates of first terrain point and spar 1 height.
4. Determine coordinates of top of spar 1 and plot at first terrain point.
5. Enter coordinates of next terrain point.
6. Plot straight line to terrain point.
7. 

8. Enter height of spar 2.
9. Plot spar 2 and skyline chord.
10. Determine and print chord slope in percent.

5.1.2 Profile Plot Program Operating Instructions

NOTE: Use the origin control to position the pen at the lower left corner of the paper.

Turn on Printer and x register key.

Enter program (starting address is +(0) (0)).

Press: CONTINUE.

Enter data:

L → z,

y_{max} → y,

and

y_{min} → x.

Press: CONTINUE.

Display:

SF - - - - - x.

Print: Scale factor.

Enter data:

$HS1$ → z, (Note: $HS1$ = 0 if the spar is not to be plotted.)

y → y,

and

x → x.

Press: CONTINUE.

Display:

x - - - - - z.

Enter data: (Terrain points)

y → y,

x → x.

Press: CONTINUE.

Display:

x - - - - - z,

SF(y) - - - y,

and

SF(x) - - - x.

After last terrain point is entered--

Press: Go To (6) (0).

Press: CONTINUE.

(Note: If the right spar (*HS*2) and the skyline chord are not to be plotted, press STOP.)

Enter data:

*HS*2 → x.

Press: CONTINUE.

Display:

0 - - - - - z,

0 - - - - - y,

and

Percent slope - - - - - x.

Print: Percent slope.

5.1.3 Profile Plot Program Listing

Step	Key	Code	x	y	z	Step	Key	Code	x	y	z	Step	Key	Code	x	y	z
00	CLR	20				40	e	12				80	e	12			
01	STP	41				41	f	15				81	b	14			
02	-	34				42	-	34				82	UP	27			
03	AC+	60				43	c	16				83	f	15			
04	4	04				44	X	36				84	X	36			
05	5	05				45	0	00				85	UP	27			
06	0	00				46	YTO	40				86	DN	25			
07	0	00				47	d	17				87	c	16			
08	XEY	30				48	FMT	42				88	X	36			
09	DIV	35				49	DN	25				89	d	17			
0a	YTO	40				4a	e	12				8a	+	33			
0b	c	16				4b	RUP	22				8b	RDN	31			
0c	RDN	31				4c	XTO	23				8c	XEY	30			
0d	7	07				4d	e	12				8d	FMT	42			
10	5	05				50	f	15				90	DN	25			
11	0	00				51	-	34				91	e	12			
12	0	00				52	c	16				92	UP	27			
13	XEY	30				53	X	36				93	AC-	63			
14	DIV	35				54	RUP	22				94	RCL	61			
15	c	16				55	e	12				95	X>Y	53			
16	X>Y	53				56	X	36				96	7	07			
17	1	01				57	RDN	31				97	a	13			
18	a	13				58	FMT	42				98	d	17			
19	UP	27				59	DN	25				99	XEY	30			
1a	1	01				5a	STP	41				9a	FMT	42			
1b	0	00				5b	GTO	44				9b	DN	25			
1c	X>Y	53				5c	4	04				9c	PSE	57			
1d	2	02				5d	c	16				9d	FMT	42			
20	4	04				60	XTO	23				a0	UP	27			
21	GTO	44				61	b	14				a1	c	16			
22	3	03				62	STP	41				a2	UP	27			
23	7	07				63	RUP	22				a3	1	01			
24	5	05				64	c	16				a4	0	00			
25	X>Y	53				65	X	36				a5	0	00			
26	2	02				66	RDN	31				a6	X	36			
27	b	14				67	+	33				a7	DN	25			
28	GTO	44				68	b	14				a8	PNT	45			
29	3	03				69	FMT	42				a9	END	46			
2a	7	07				6a	DN	25									
2b	2	02				6b	DIV	35									
2c	.	21				6c	RUP	22									
2d	5	05				6d	d	17									
30	X>Y	53				70	XEY	30				Storage					
31	3	03				71	DIV	35				0			8		
32	6	06				72	RDN	31				1			9		
33	GTO	44				73	-	34				2			a		
34	3	03				74	YTO	40				3			b		
35	7	07				75	c	16				4			c		
36	1	01				76	DN	25				5			d		
37	XTO	23				77	.	21				6			e		
38	c	16				78	8	10				7			f		
39	PNT	45				79	XTO	23									
3a	STP	41				7a	f	15									
3b	RDN	31				7b	.	21									
3c	+	33				7c	2	02									
3d	XTO	23				7d	XTO	23									

5.2 Load Path Plot

This program determines and plots the load path of the running skyline between supporting spars. The procedure of Carson and Mann[5] has been programed on the Hewlett-Packard 9100 Calculator, Printer, Plotter System. This program is designed to follow the profile plot program, although it can be run separately.

5.2.1 Load Path Plot Program Flow

(NOTE: This section contains symbols and equations discussed in Carson and Mann.[5])

1. Input skyline characteristics:

   h = anchor elevation difference,

   L = anchor span distance,

   T_A = haulback allowable tension,

   w_1 = haulback weight per foot,

   and

   w_3 = main and grapple-opening line weight per foot.

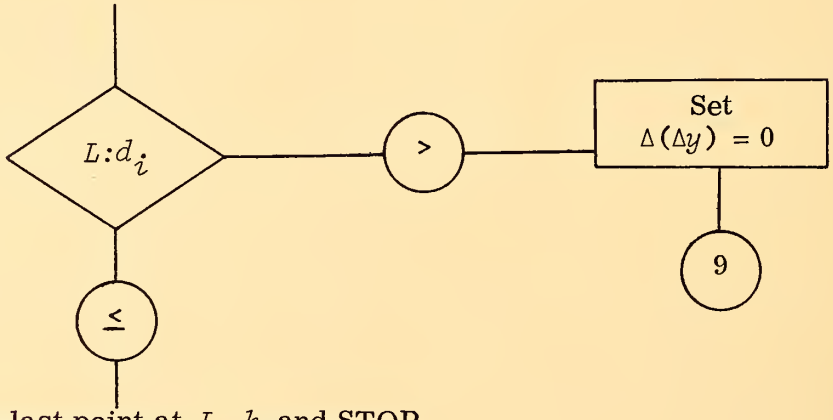
2. Input scale factor, SF.

3. Input gross payload weight, $(W_G)_{INPUT}$

4. Initialize -

   Set initial coordinates $(d,\ \Delta y)$ at $(0, 0)$.

5. Establish Δd and determine $d_i = d_{i-1} + \Delta d$.

6. 

7. Plot last point at L, h and STOP.

8. Prepare $\Delta(\Delta y) = L/100$ for second pass.

9. Prepare $(\Delta y)_{CHORD}$.

10. Determine new $\Delta y = (\Delta y)_{CHORD} + \Delta(\Delta y)$.

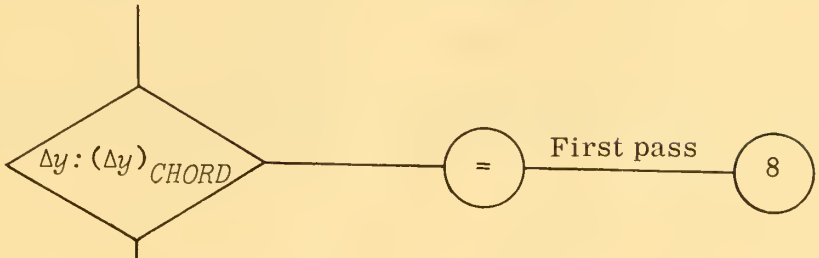
11. Determine V_1^1 and H_1 in a square root routine.

12. Determine V_2^2 and H_2 in a square root routine.

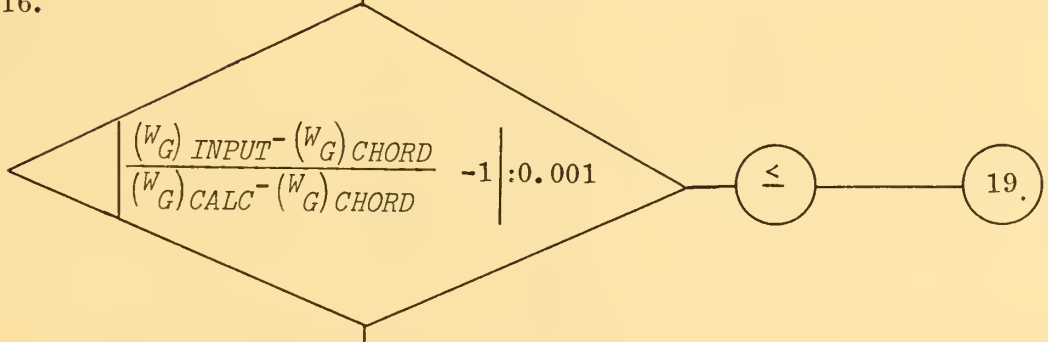
13. Determine V_s^2 and H_s.

14. Determine $(W_G)_{CALC}$.

15.



16.



17. Prepare $\Delta(\Delta y) = \{(\Delta y)_{CALC} - (\Delta y)_{CHORD}\} \left\{ \frac{(W_G)_{INPUT} - (W_G)_{CHORD}}{(W_G)_{CALC} - (W_G)_{CHORD}} \right\}$

$+ (\Delta y)_{CHORD}$.

18. Go to step 9.

19. Prepare and plot (d, Δy) and return to step 5.

5.2.2 Load Path Plot Program Operating Instructions

NOTE: Press STOP and use the origin controls to locate the pen at the top of spar 1.

Turn on x in Printer.

Enter Program A: (starting address is +(0) (0)).

Enter Program B: (starting address is -(0) (0)).

Load:

SF = scale factor (same as profile plot) → a,

L = skyline span (same as profile plot) → b,

h = anchor elevation difference (see fig. 6) → c,

w_3 = weight per foot of main and operating line → +9,

w_1 = weight per foot of haulback → +8,

T_A = operating tension (usually one-third of haulback breaking strength) → +7.

Press: END (or Go To +(0) (0)).

Enter: W_G, gross payload (combined log and carriage weight) → x.

Press: CONTINUE.

If the plot of more than one gross payload is desired, repeat the last three steps.

5.2.3 Load Path Program Listing

Load Path - Page

Step	Key	Code	Step	Key	Code	Step	Key	Code
00	CHS	32	40	c	16	80	X>Y	53
01	XEY	30	41	UP	27	81	9	11
02	b	14	42	b	14	82	3	03
03	+	33	43	CHS	32	83	c	16
04	EEX	26	44	AC+	60	84	XEY	30
05	2	02	45	RCL	61	85	b	14
06	DIV	35	46	CHS	32	86	DIV	35
07	RUP	22	47	XTO	23	87	f	15
08	XTO	23	48	f	15	88	X	36
09	4	04	49	POL	62	89	e	12
0a	f	15	4a	1	01	8a	XEY	30
0b	XEY	30	4b	RCT	66	8b	-	34
0c	b	14	4c	XEY	30	8c	RDN	31
0d	DIV	35	4d	RDN	31	8d	X	36
10	c	16	50	DIV	35	90	GTO	44
11	X	36	51	YTO	40	91	1	01
12	DN	25	52	5	05	92	2	02
13	+	33	53	DN	25	93	GTO	44
14	YTO	40	54	X	36	94	+	33
15	e	12	55	UP	27	95	1	01
16	XFR	67	56	RCL	61	96	9	11
17	7	07	57	POL	62	97	UP	27
18	SFL	54	58	XEY	30	98	X	36
19	GTO	44	59	XFR	67	99	UP	27
1a	SUB	77	5a	9	11	9a	RCL	61
1b	9	11	5b	X	36	9b	POL	62
1c	7	07	5c	2	02	9c	XEY	30
1d	XTO	23	5d	DIV	35	9d	XFR	67
20	5	05	60	DN	25	a0	8	10
21	YTO	40	61	-	34	a1	X	36
22	6	06	62	XFR	67	a2	2	02
23	POL	62	63	6	06	a3	DIV	35
24	UP	27	64	+	33	a4	YTO	40
25	c	16	65	XFR	67	a5	-	34
26	UP	27	66	4	04	a6	e	12
27	b	14	67	UP	27	a7	DN	25
28	AC-	63	68	CLX	37	a8	UP	27
29	f	15	69	X=Y	50	a9	X	36
2a	CHS	32	6a	0	00	aa	RDN	31
2b	XTO	23	6b	2	02	ab	-	34
2c	f	15	6c	d	17	ac	YTO	40
2d	RUP	22	6d	XEY	30	ad	-	34
30	GTO	44	70	-	34			
31	SUB	77	71	XEY	30			
32	9	11	72	RDN	31			
33	7	07	73	-	34			
34	YE	24	74	RDN	31			
35	5	05	75	DIV	35			
36	+	33	76	UP	27			
37	+	33	77	DN	25			
38	YE	24	78	1	01			
39	6	06	79	-	34			
3a	DN	25	7a	|Y|	55			
3b	-	34	7b	EEX	26			
3c	DN	25	7c	3	03			
3d	+	33	7d	CHS	32			

Storage

0	8
1	9
2	a
3	b
4	c
5	d
6	e
7	f

-Page cont'd.

Step	Key	Code	x	y	z	Step	Key	Code	x	y	z	Step	Key	Code	x	y	z
b0	f	15															
b1	RCL	61															
b2	DIV	35															
b3	DN	25															
b4	X	36															
b5	UP	27															
b6	X	36															
b7	1	01															
b8	+	33															
b9	RUP	22															
ba	IFG	43															
bb	ARC	72															
bc	CHS	32															
bd	RUP	22															
c0	DIV	35															
c1	UP	27															
c2	XFR	67															
c3	-	34															
c4	f	15															
c5	XEY	30															
c6	DIV	35															
c7	DN	25															
c8	RDN	31															
c9	X	36															
ca	RDN	31															
cb	+	33															
cc	DN	25															
cd	SQR	76															
d0	+	33															
d1	RUP	22															
d2	RCL	61															
d3	DIV	35															
d4	DN	25															
D5	X	36															
d6	XFR	67															
d7	-	34															
d8	e	12															
d9	-	34															
da	DN	25															
db	SUB	77															

Storage			
0		8	
1		9	
2		a	
3		b	
4		c	
5		d	
6		e	
7		f	

Load Path + Page

Step	Key	Code
00	XTO	23
01	d	17
02	PNT	45
03	CLR	20
04	FMT	42
05	DN	25
06	b	14
07	XEY	30
08	1	01
09	0	00
0a	DIV	35
0b	DN	25
0c	AC+	60
0d	f	15
10	UP	27
11	b	14
12	X>Y	53
13	3	03
14	0	00
15	c	16
16	XTO	23
17	e	12
18	SFL	54
19	RCL	61
1a	UP	27
1b	XFR	67
1c	5	05
1d	PNT	45
20	a	13
21	X	36
22	RUP	22
23	X	36
24	CLX	37
25	RDN	31
26	CHS	32
27	XEY	30
28	IFG	43
29	3	03
2a	4	04
2b	GTO	44
2c	0	00
2d	4	04
30	GTO	44
31	-	34
32	0	00
33	0	00
34	FMT	42
35	DN	25
36	CLR	20
37	FMT	42
38	UP	27
39	END	46

Step	Key	Code

Step	Key	Code

Storage

0	8
1	9
2	a
3	b
4	c
5	d
6	e
7	f

HEWLETT PACKARD

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

College, Alaska	Portland, Oregon
Juneau, Alaska	Roseburg, Oregon
Bend, Oregon	Olympia, Washington
Corvallis, Oregon	Seattle, Washington
La Grande, Oregon	Wenatchee, Washington

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.